The effects of data selection on the assimilation of AIRS data

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Outline

- Description of the data assimilation system
- Description of experimental setups
  - Channel selection and weights
  - Spatial subsetting
- Assimilation results
  - Data coverage and Observed-Background statistics
  - Cloud detection
  - Forecast Skill
- Discussion on the effect of water vapor channels
- Conclusions and future plans

AIRS Assimilation Experiments

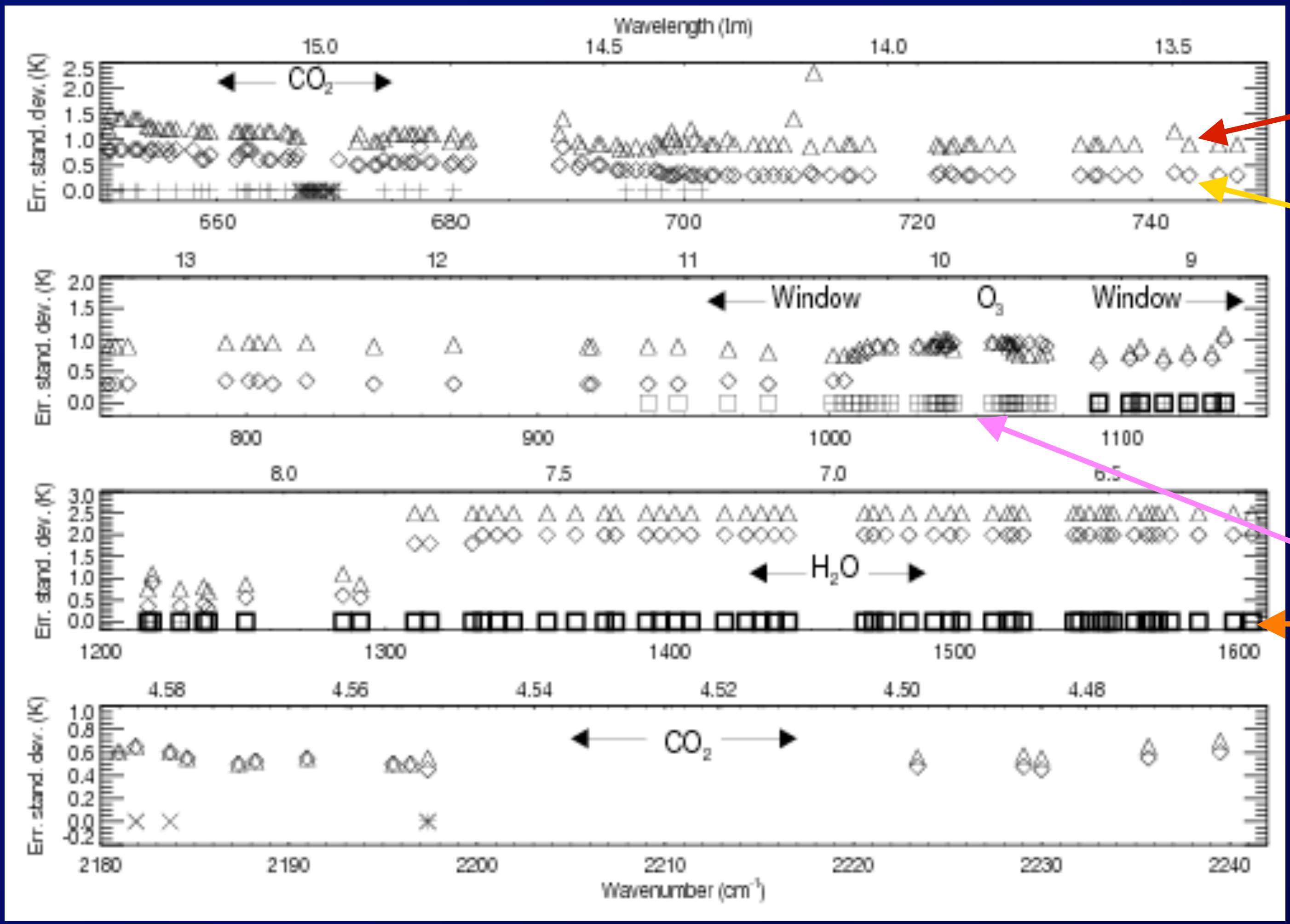
fvSSI Assimilation System

- NCEP SSI (Spectral Statistical Interpolation) analysis and satellite data (Derber et al) T63L64
- Finite volume GCM (Lin et al.) 1^o X 1.25^o
- AIRS and AMSU-A radiances assimilated in a variety of ways including
  - warmest FOV or center FOV in a golfball
  - clear radiances with different channel selections and specified errors
- Progress since last presentation (September):
  - Completed a full set of experiments with Aqua AMSU-A radiances as well as AIRS on NCCS SGI platform (decommisioned at end of Jan. 2006)

Step 1: Find optimal set of channels and errors

- Start with two sets of channel errors (Small and Large)
- Channel errors affect assimilation in 2 ways
  - Affects the weight a channel receives in the analysis (how much to weight data vs forecast and other observations)
  - Affects quality control threshold (toss data that has difference from forecast > 3σ or 4.5K)
- Try different channel selections using two sets of errors
  - Start with nearly full channel set (note: do not use channels > 2240 cm^{-1} currently)
  - Eliminate 6.7 μm water vapor channels (1080-1620 cm^{-1})
  - Eliminate also 9.7 μm ozone channels (920-1080 cm^{-1})

Channel errors and selection



Large errors

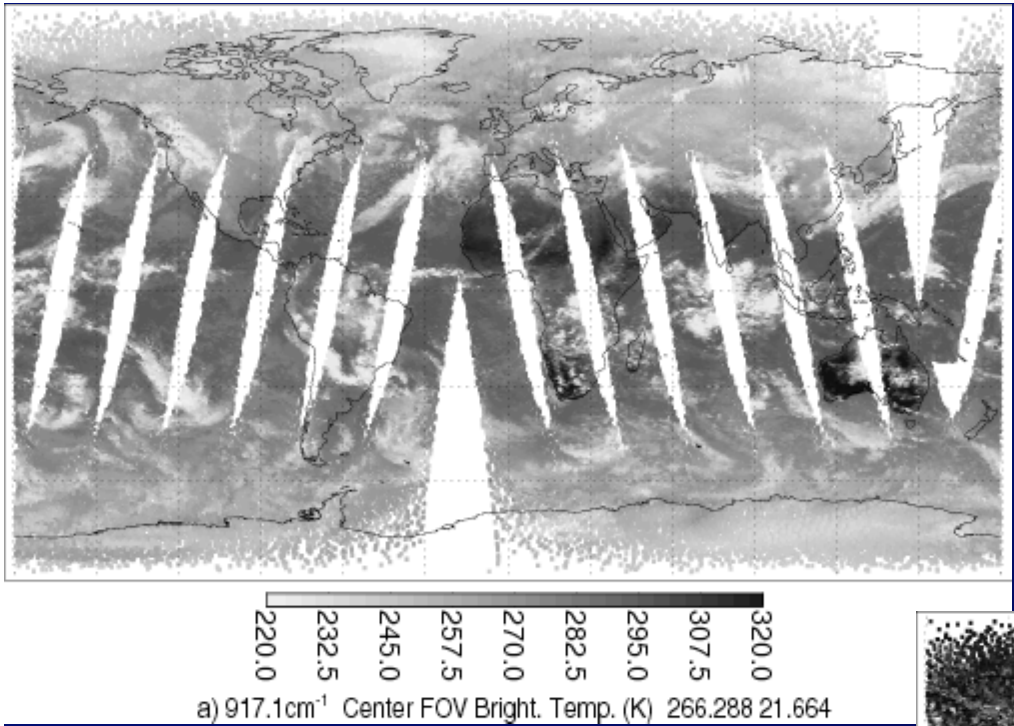
Small errors

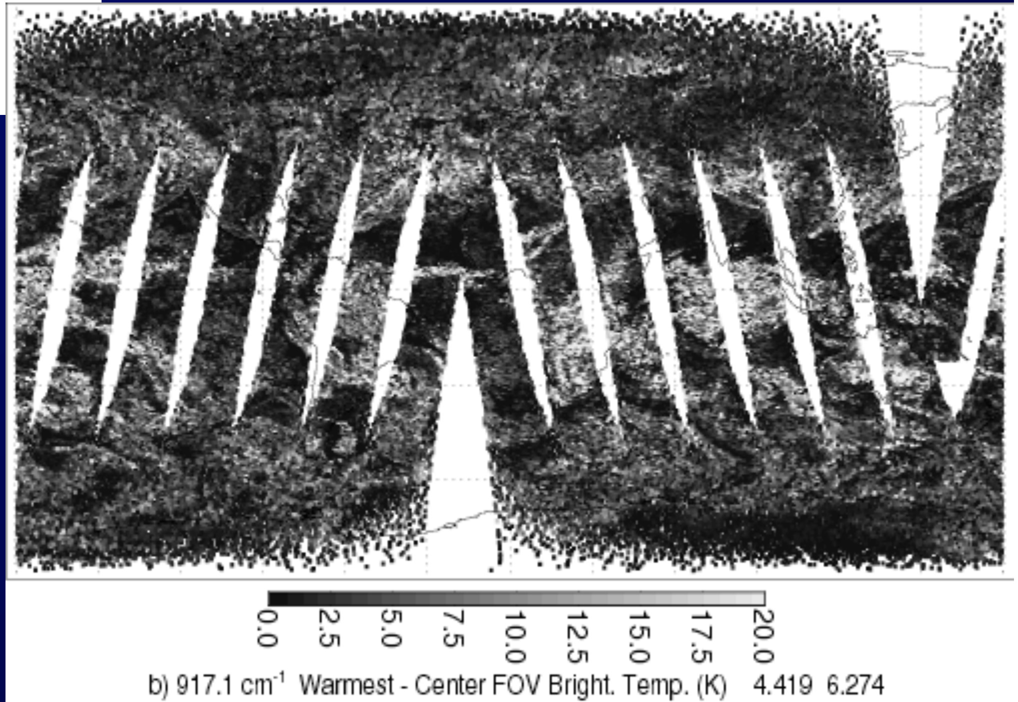
Try eliminating H_2O channels and ozone channels

Step 2: Use optimized channel set to investigate effects of

- Assimilating AIRS and Aqua AMSU-A separately and together
- Different spatial subsetting (warmest FOV vs center FOV)
- Not feeding back humidity analysis to model

Center FOV brightness temps in 11 μm window 20 December 2002





Warmest-Center FOV radiances in 11 μm window (mean difference 4.4K, σ= 6.3K). Largest differences occur in and on edges of cloudy areas where forecast sensitivity is expected to be highest.

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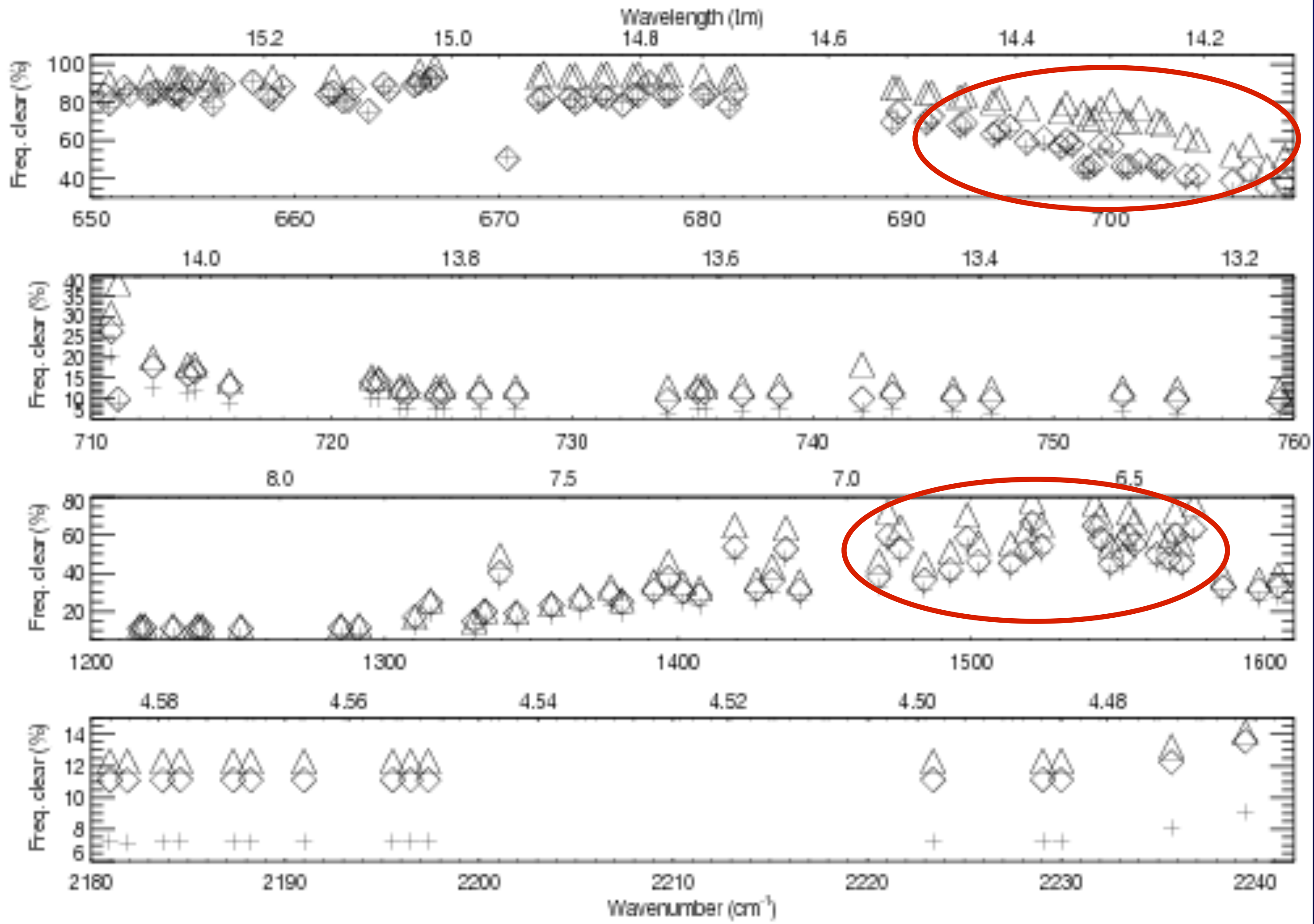
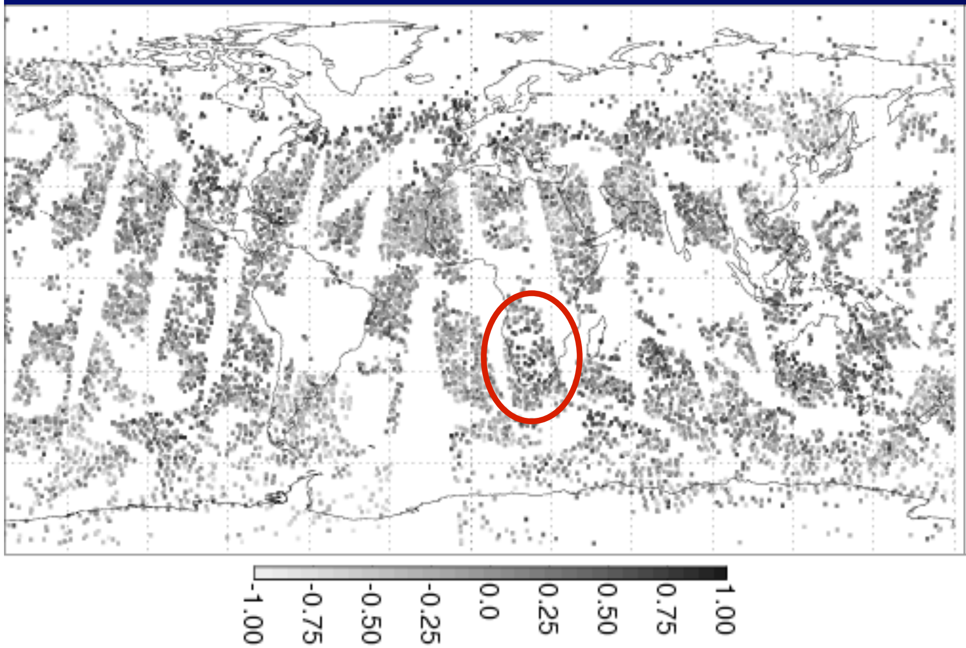
Percentage of input data accepted by analysis: Δ: Large errors, warmest FOV; ◇: Small errors, warmest FOV; +: Small errors, center FOV



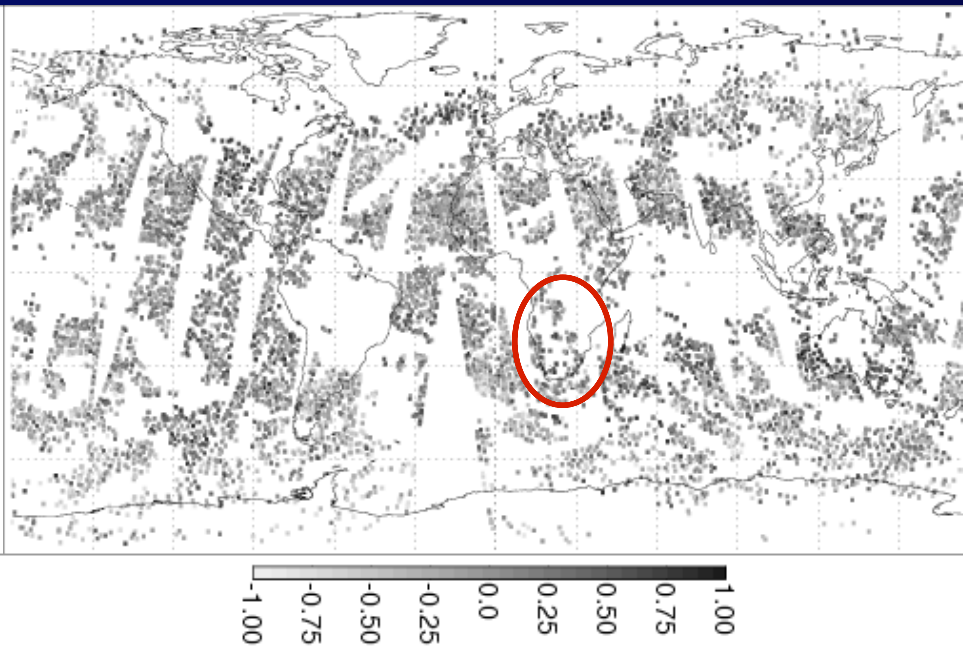
Specification of channel errors can play a significant role in determining how much data enters analysis (can be larger effect than FOV selection method)

Coverage: Warmest FOV (left) vs Center FOV (right)

Note: warmest FOV has ~10% more observations accepted for this mid-tropospheric temperature channel



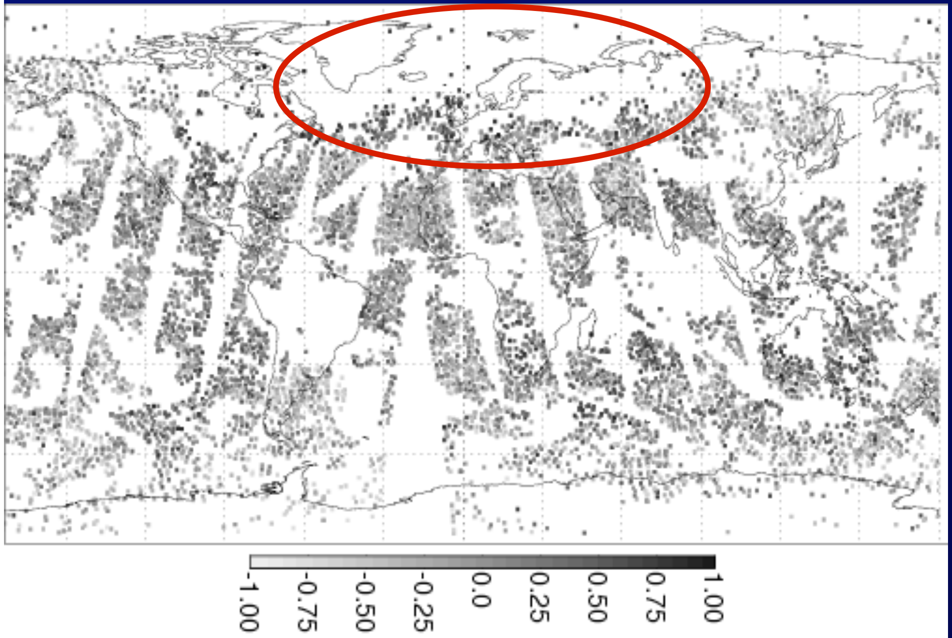
b) 704.4cm^{-1} warmest FOV (Small) 9250 -0.002 0.380



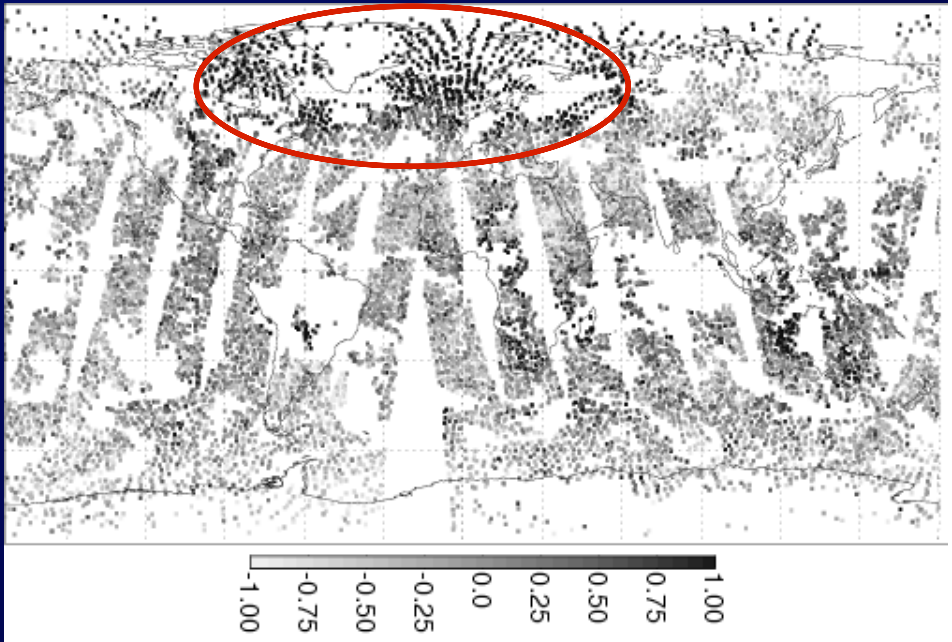
a) 704.4cm^{-1} center FOV (Small) 8220 0.005 0.380

Coverage: Small errors (left) vs Large errors (right)

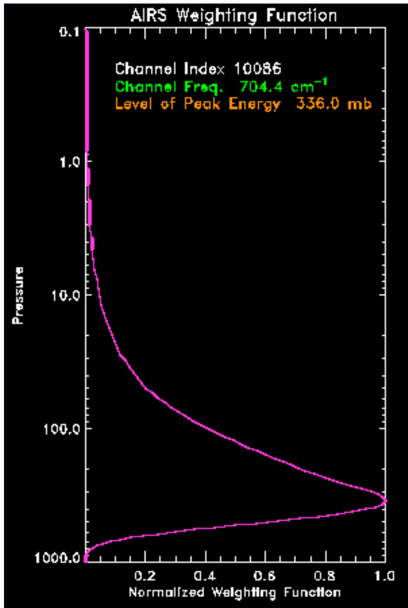
- Note: Large error set allows in ~40% more observations, particularly at higher latitudes where Obs-Calcs are larger



b) 704.4cm^{-1} warmest FOV (Small) 9250 -0.002 0.380

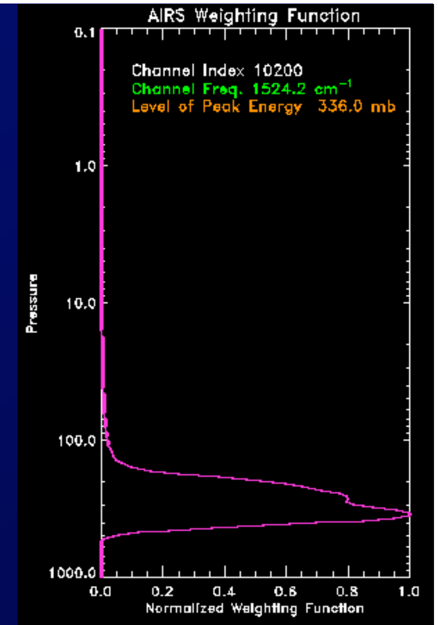


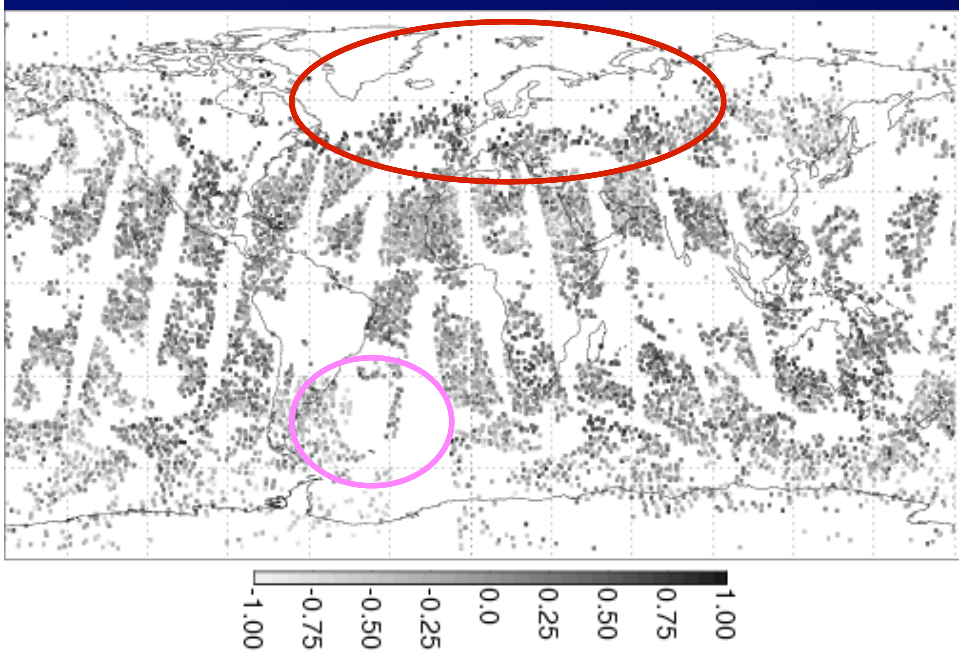
c) 704.4cm^{-1} warmest FOV (Large) 13079 0.088 0.628



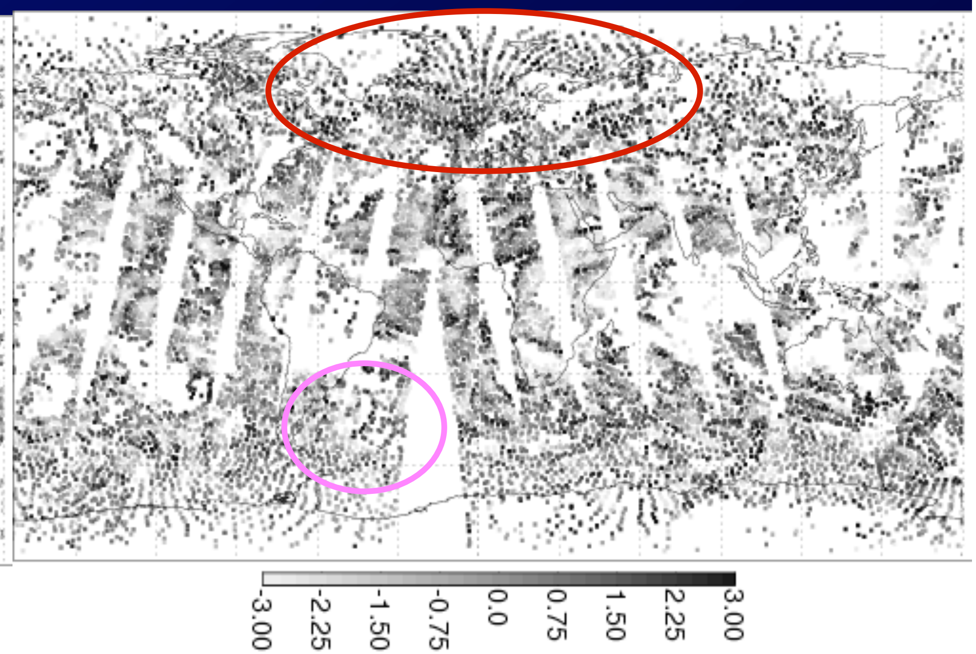
Comparing coverage and Obs-Calc of temperature (704.4 cm^{-1}) and water vapor channels (1524.4 cm^{-1}) that peak at similar altitudes (336 mb)

Water vapor channel has significantly more coverage (~50%!) and larger Obs-Calc due to 1) larger quality control threshold 2) more sharply peaked weighting function (more often peaks above low clouds). This channel has more small-scale structure in Obs-Calc due to forecast humidity errors. This leads to water vapor channels having large impact on temperature analysis.



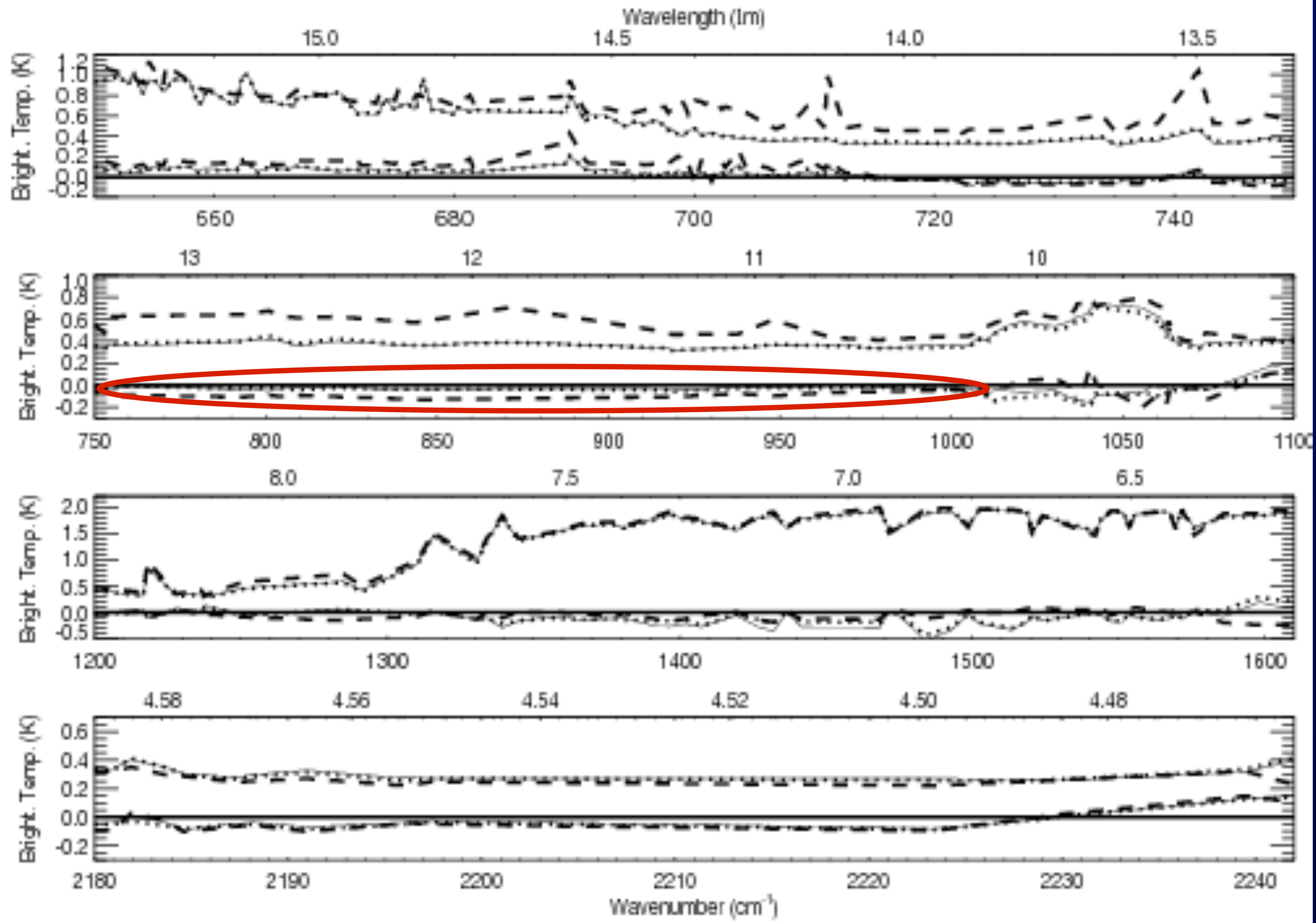


b) 704.4cm^{-1} warmest FOV (Small) 9250 -0.002 0.380



d) 1524.4cm^{-1} warmest FOV (Large) 14668 0.043 1.877

Observed – Calc (forecast) brightness temps mean (top curves); standard deviation (bottom curves)



Dashed: Large errors (warmest FOV)
Solid: Small errors (warmest FOV)
Dotted: Small errors (center FOV)

FOV selection does not impact Obs-Calc (good)

As expected, changing the channel errors (quality control thresholds) does impact Obs-Calc. Note slightly more negative mean with Large Errors (more cloud contamination?)

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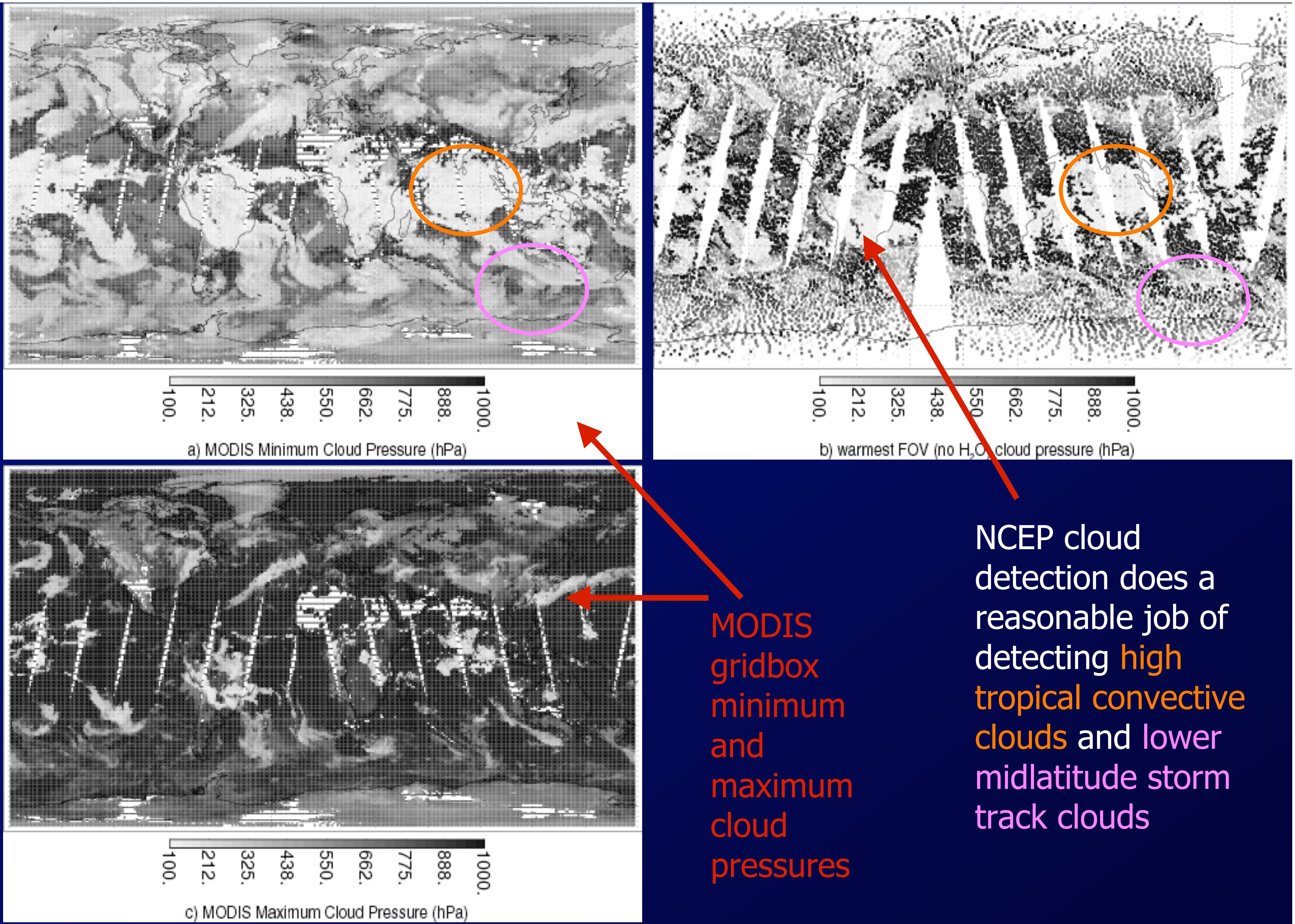
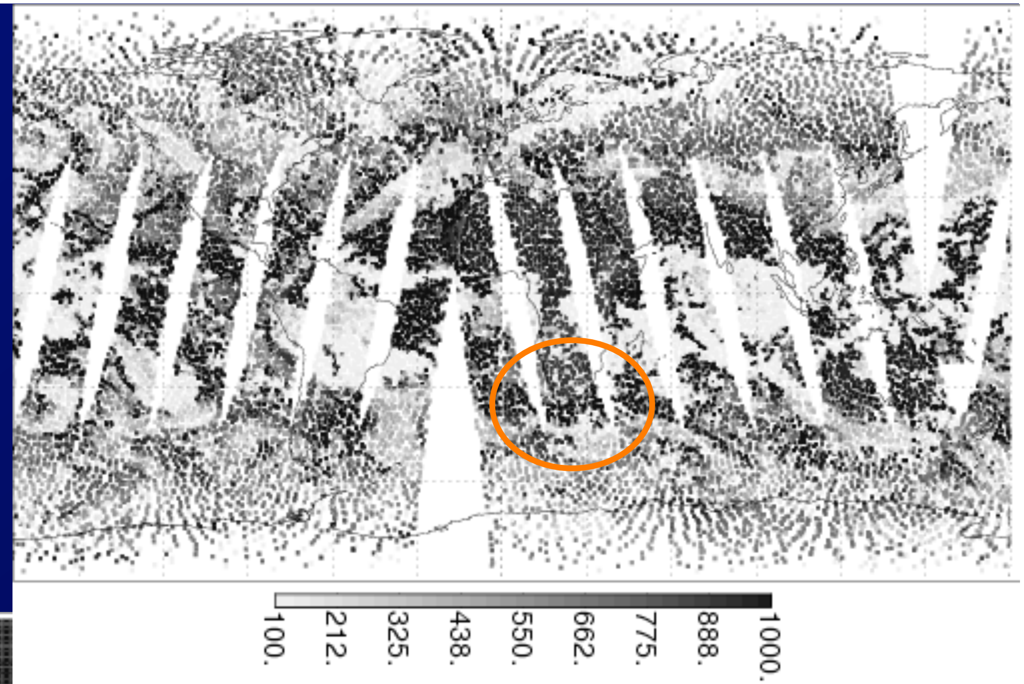


MODIS gridbox minimum and maximum cloud pressures

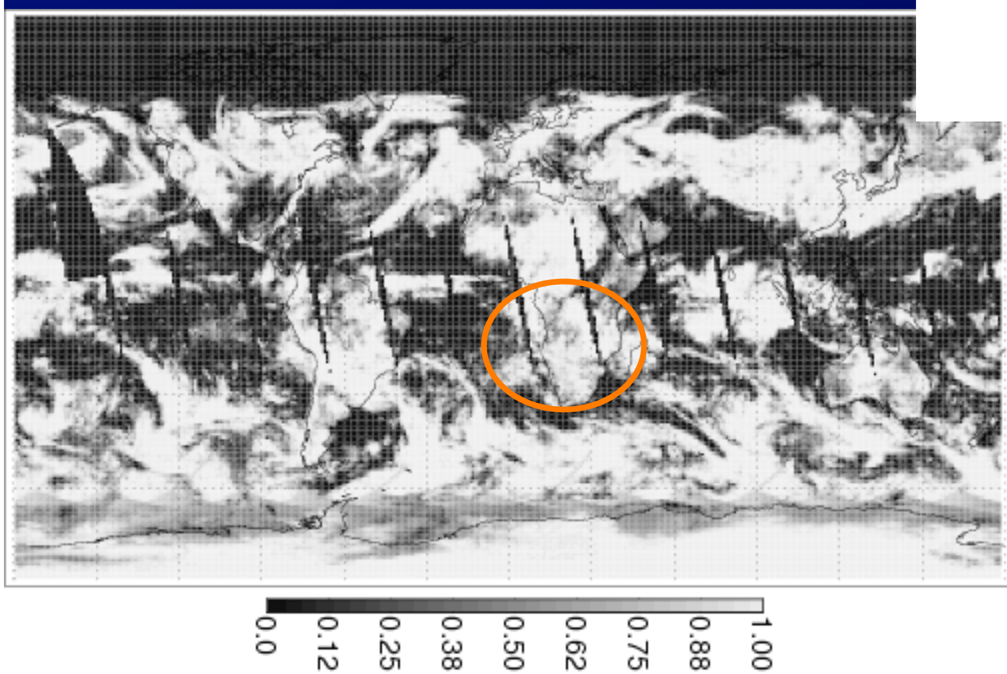
NCEP cloud detection does a reasonable job of detecting high tropical convective clouds and lower midlatitude storm track clouds

Potential cirrus contamination

MODIS SW infrared cirrus fraction



b) warmest FOV (no H_2O) cloud pressure (hPa)



d) MODIS mean cirrus fraction SW infrared

As we have seen before, the type of cloud detection algorithm in fvSSI can have difficulty with thin cirrus over warm land. This requires more attention.

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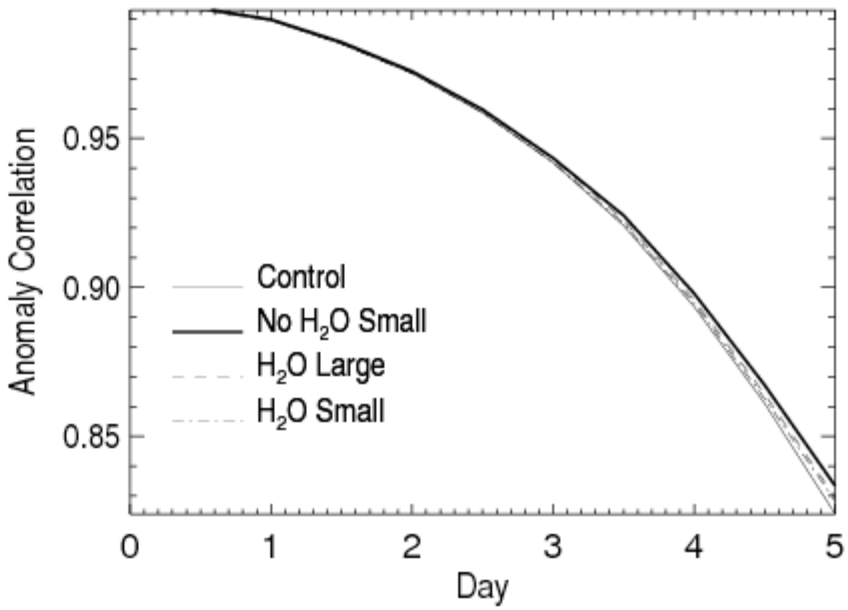
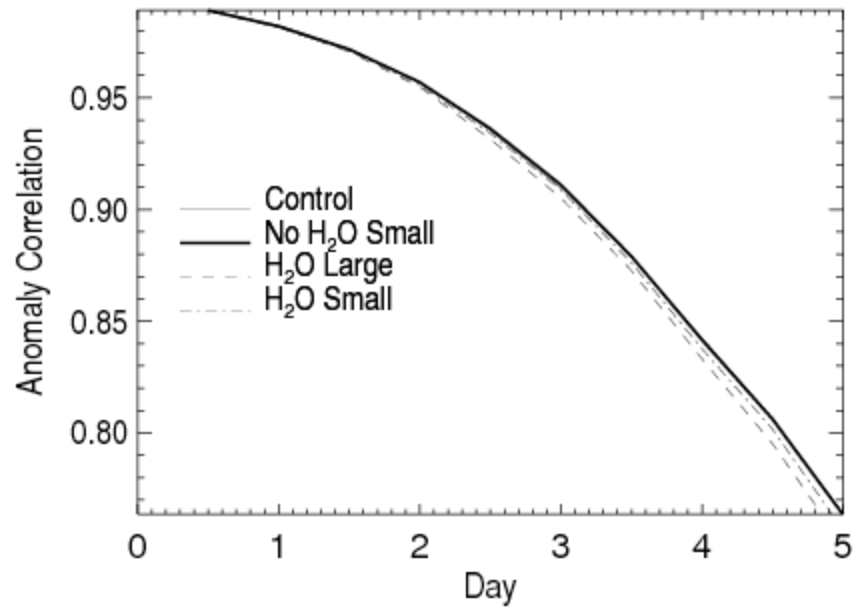
Northern hemisphere



Southern hemisphere



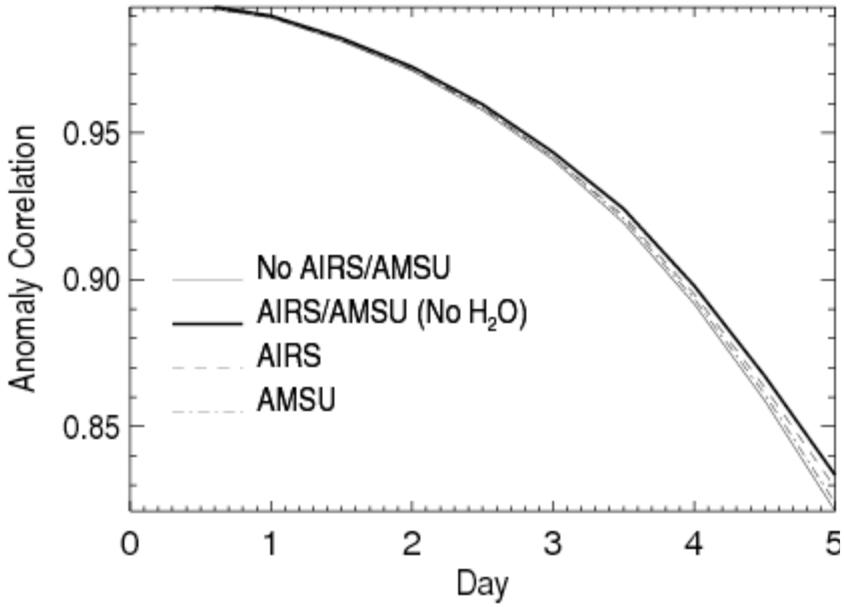
All experiments with AIRS in NH show positive impact (paired t-test shows statistical significance, Control has Aqua AMSU-A)
Best results obtained with Small error set and no H_2O channels

In SH, best results also obtained with Small error set and no H_2O channels (neutral impact)

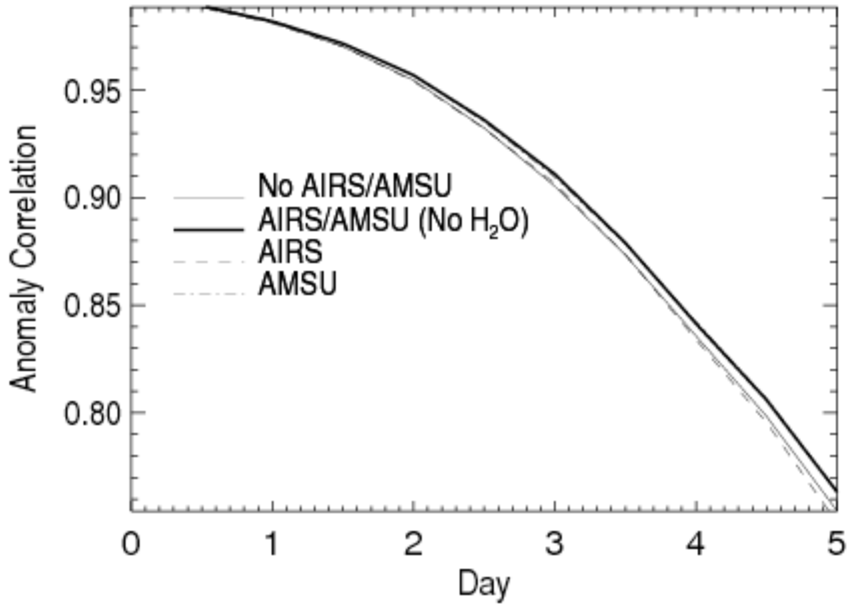
Note: results are similar to those obtained by McNally et al. for a similar time period (ECMWF high resolution DAS)

AIRS/AMSU impacts separately and together

Northern hemisphere



Southern hemisphere



NH: Positive imact from both AIRS and AMSU separately

Slightly more impact from AIRS alone than AMSU

AIRS+AMSU > AIRS alone + AMSU alone

SH: Positive imact from AMSU

Neutral impact from AIRS in addition

Other forecast results and summary

- Difference in forecast skill between warmest and center FOV was not very significant.
- Removing ozone channels in addition to water vapor channels had little impact.
- Difference in forecast skill between Large and Small errors not significant when water vapor channels were excluded.
- Although error specification and spatial subsetting methods can have a large effect on data coverage, in our system, these had little impact on forecast skill.
- Use of Aqua AMSU-A helps to improve AIRS assimilation.
- 6.7 μm channels had a negative impact on forecast skill scores.
- Looked at whether there is negative interaction between the analyzed humidity and model physics (by configuring system to not feed back analyzed field to model). There is more going on than interaction with physics!

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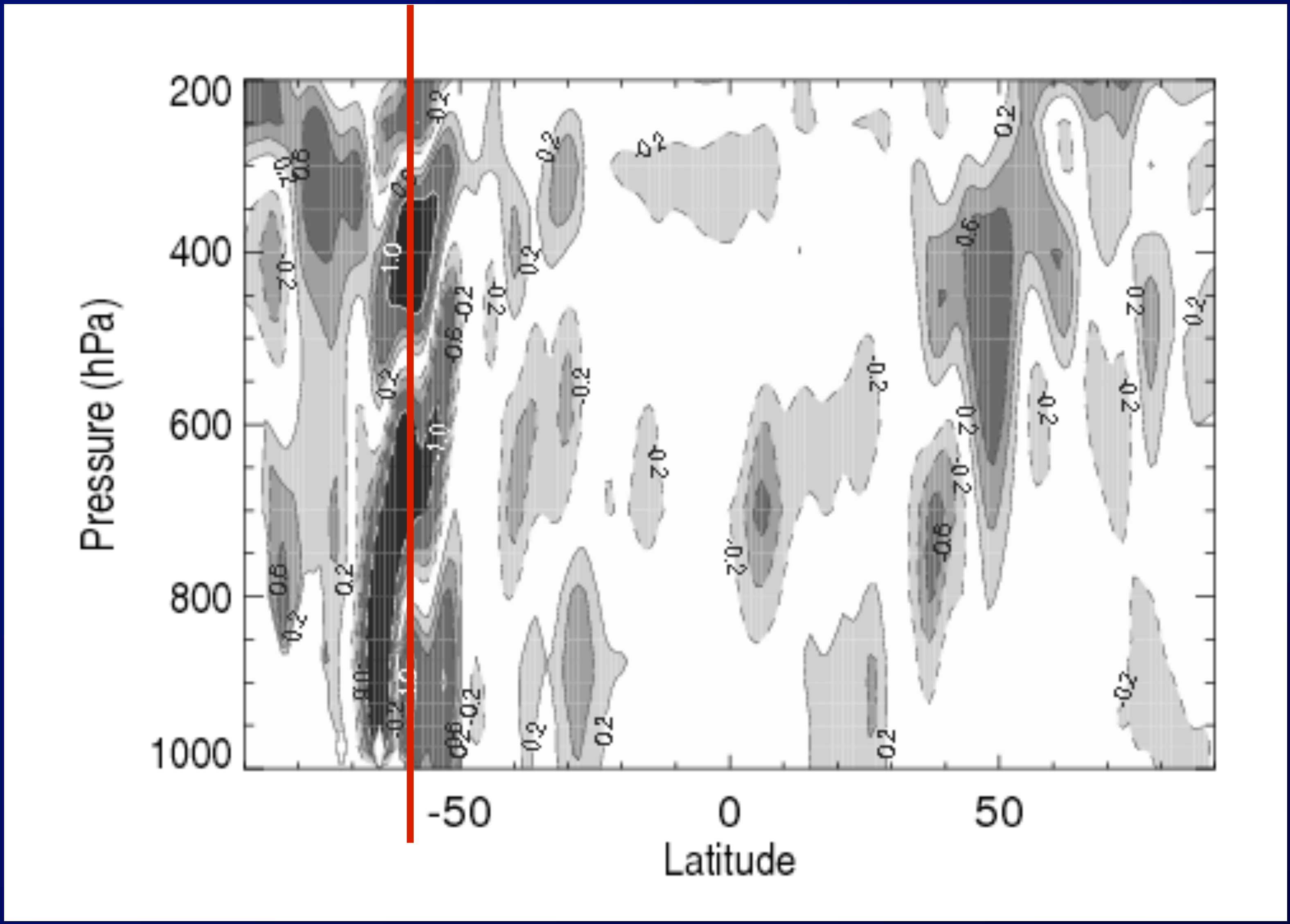
Analysis increments from AIRS/AMSU only: Temperature changes from 6.7 μm channels

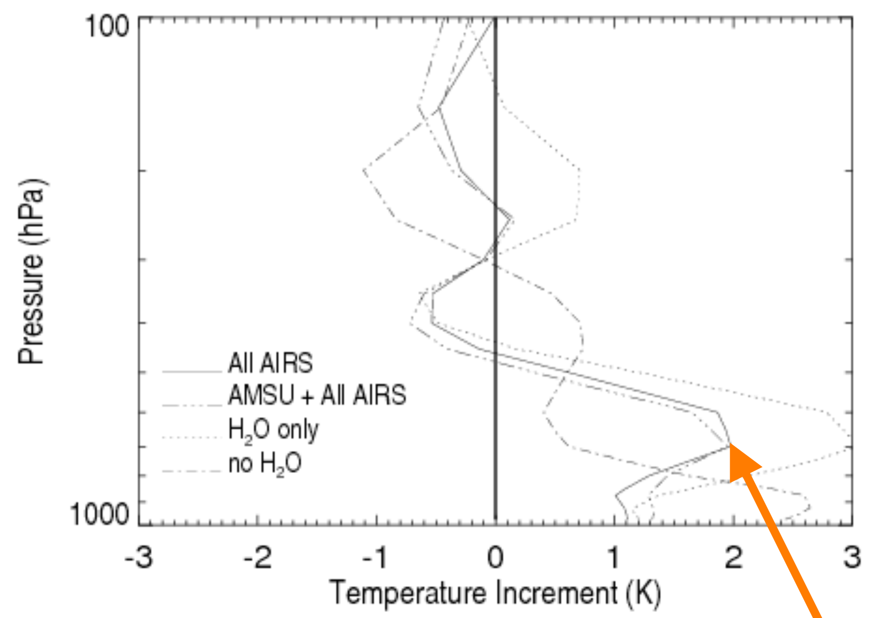


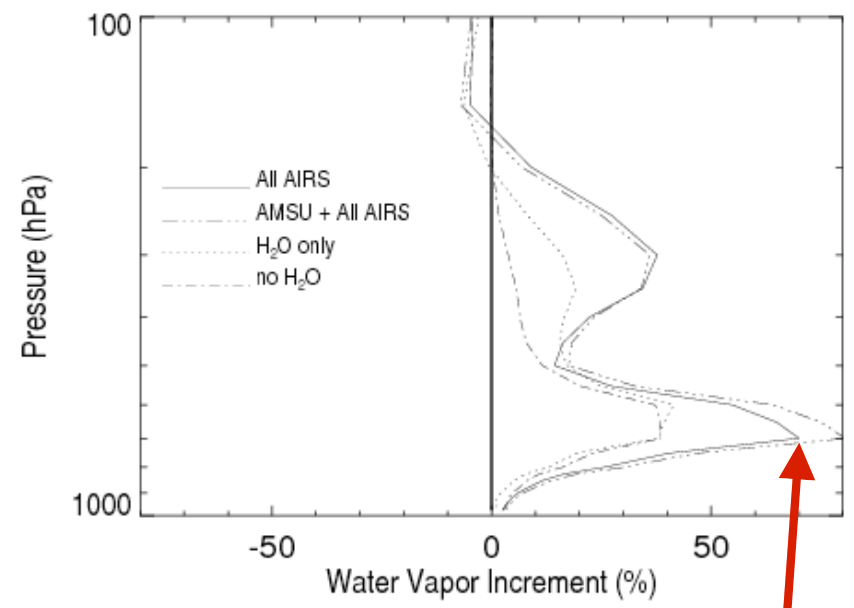
Cross section through 122.5 W

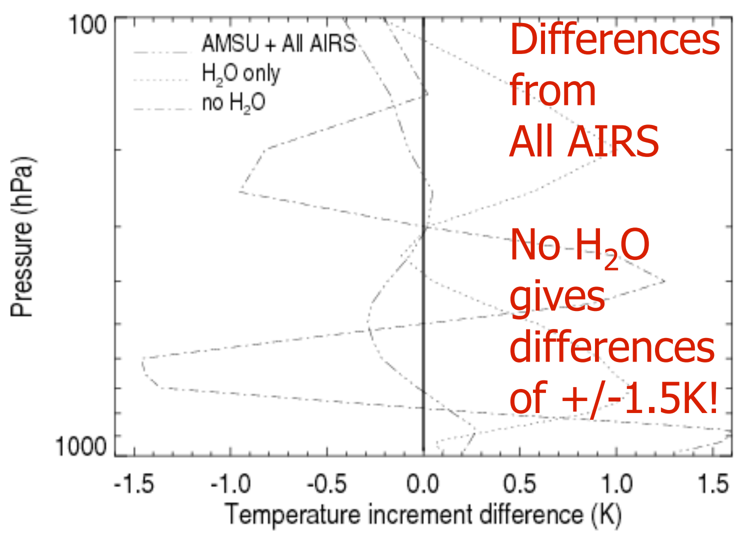
0.2K contours;
Solid: +
Dashed: -

Focus on oscillating vertical structure at 60S

Analysis increments: AIRS/AMSU radiances only







Differences from All AIRS

No H_2O gives differences of +/-1.5K!

6.7 μm channels dominate the shape of temperature increments when used.

All channels together also produce larger water vapor increments than 6.7 μm or 15 μ m alone.

We don't know what where the truth lies! Forecast skills can give a clue. Need better error estimates (especially for forecast).

Conclusions and ongoing work

- We have shown significant positive impact on forecast skill from the AIRS/AMSU combination in both hemispheres.
- While different spatial subsetting (warmest vs center FOV) and specified channel errors can have a relatively large effect on coverage within the analysis, these did not significantly affect forecast skill in our system (somewhat of a surprise).
- Channels in the 6.7 μm band have a significant effect on the temperature analysis. There is useful information in the data, but it cannot be exploited unless the forecast and observation errors are specified very well. Note: this is extremely difficult! If not used properly, these channels can cause negative impacts on forecast skill.
- Have not yet demonstrated positive impact from cloud-cleared radiances. Obs-calcs look good, but need to take into account error inflation (requires work on analysis system).
- Integrate results into GMAO's next-generation fvGSI system and provide results to NCEP.